4.0 Sewer System Evaluation Study

4.1 Overview

The Sewer System Evaluation Study consists of a wide range of activities as defined by the Consent Decree (CD). The primary assessment conducted for each of the City of Baltimore's sewersheds is important for characterizing the condition of the system as it provides important insight into the historical nature of the collection system. The testing and inspection of the wastewater collection system, in what is termed sewer system evaluation survey (SSES), is a significant part of the overall evaluation of the sewershed. These SSES activities include conducting flow monitoring and rainfall data collection programs, completing the inspection of manholes and other sewer structures located within the collection system, performing internal inspection of sewers 8-inches in diameter and larger, conducting smoke and dyed-water testing, the preparation, calibration and validation of a hydraulic model, the identification of critical sewer system components within the collection system, and establishing criticality ratings for these components. All data was compiled to formulate a long term rehabilitation and corrective action plan that includes an implementation schedule and estimates of probable costs.

The City provided guidance and general direction to the sewershed consultants to assure that all tasks completed in support of this study are prepared in a standardized format to facilitate the collection and review of the data for compliance with the requirements of the CD. The SSES emphasizes on the inspection of sanitary sewers 8-inches and larger in diameter, including all sewer structures per Paragraph 9 of the CD. This information will be used in the preparation of a comprehensive corrective action plan for the sewershed. As part of the Outfall Sewershed SSES, 327,771 linear feet (LF) of gravity sewer lines and approximately 2,195 manholes were inspected.

4.2 Manhole Inspections

Manholes are the principal means to access a collection system. As such, effective manhole inspection is important in characterizing the overall condition and connectivity of the collection system. The manhole inspections completed for this project typically served multiple roles, which included characterizing the condition of the structure, identifying system connectivity, assisting in defining the general condition of the sewer segments connected to the structure, providing defect observation data required for the condition assessment and development of subsequent repair recommendations for the structure, and identifying additional potential sources of Inflow and Infiltration (I/I) into the collection system. The inspections also provided updated system attribute data such as pipe diameters, structure type and depths, network connectivity, and sewer system configuration. Collection of this data during the detailed inspections also allowed the City's GIS to be updated accurately and efficiently. These updates included removing structures that were originally identified as sewer structures in the GIS

system but were actually not, and accurately updating the GIS with newly identified sewers and sewer structures that were not originally shown in the GIS.

Manholes were inspected as required by the CD in accordance with general guidelines outlined in the Environmental Protection Agency's (EPA) SSES Handbook, the American Society of Civil Engineers (ASCE) Manhole Inspection and Rehabilitation Manual 92, and the newly defined requirements of the National Association of Sewer Service Companies (NASSCO) Manhole Assessment and Certification Program (MACP). All inspections were completed under the guidance of MACP certified inspectors. Manholes that could not be located or opened for inspection were documented for additional action. These structures will be inspected and incorporated into the City's overall rehabilitation plan.

Wherever physical manned-entry internal inspections were required, these were conducted in accordance with OSHA's 29 CFR 1910.146 Confined Space Entry Requirements.

Manhole inspections were conducted by Dewberry/Brown and Caldwell's sub-contractor, Phoenix Engineering, utilizing the Manhole Inspection Application Software (MIAS) Version 3.4 developed by the City of Baltimore DPW.

MIAS allowed field crews to collect detailed inspection information about the physical characteristics of a manhole or structure, identify any sewer connections to the structure and record details about the environment surrounding the manhole that was needed to accurately characterize the condition of the manhole or structure. In addition to the characteristics of the structure, such as the structure's size, shape and construction material, the MIAS application allowed defects and potential sources of I/I to be recorded. MIAS was designed to provide internal methods that link the inspection photographs of the manhole or defect observations to the manhole database record, making them available for easy review and preparation of formal reports to the City or for review at a later date. MIAS also allows access to the GIS and aerial maps, which provided the inspector with additional system or location information in the field to allow them to accurately complete the inspection and update the detailed inspection database.

The following is a brief description of the process involved in the collection of manhole inspection data for the Outfall Sewershed. The following descriptions are not intended to cover all aspects of the work performed, rather to provide the reader with a general understanding of the data collection and review process.

- A manhole inspection crew consisting of 2 inspectors uses a 1" = 100' scale GIS map to identify manholes to be inspected. This map contains information such as street names, manhole location and ID, flow direction and connectivity of the system with all other upstream and downstream manholes.

- The crew selects a manhole from the database list of manholes and goes to the location where the manhole is shown on the GIS map and performs a visual search in an effort to locate the manhole or structure for inspection. If found, the manhole is located utilizing GPS or other typical survey technique such as triangulation measurements, and then the manhole is inspected. If the manhole is not found, the position is estimated based on the surrounding objects shown on the map and methods such as probing the soil are used to try to locate the manhole for inspection.

- If a manhole structure is not found after a normal field investigation or cannot be opened, it is noted as "Cannot Locate (CNL)" or "Cannot Open (CNO)" in the MIAS database and sent to Dewberry/Brown & Caldwell's subcontractor REI Drayco for a specialized field investigation. Before the specialized field investigation is performed, CCTV records are checked to confirm that the manhole exists for CNL manholes. The specialized field investigation involves the use of a CCTV push camera with sonar signaling that is captured overland once the camera is inside a CNL manhole. If the manhole is covered by grass or pavement, the manhole is uncovered and the manhole height is adjusted. CNO manhole covers are often unbolted and lubricated to permit access by the inspection team. Once the manhole is made accessible, the inspection team is notified and they revisit the site and complete the inspection. If the manhole cannot be inspected because of impractical circumstances, it is placed on the city's Asset Accounting Database and the exact conditions of the failed inspection are documented for further evaluation under the City's overall rehabilitation plan.

- Once a manhole is located and opened, the MIAS survey is completed. The format of the MIAS inspection form prompts the inspector to begin their inspection by recording features such as the structure's location, then features and defects are recorded starting at the top of the manhole structure and working down to the invert. These entries include frame/cover type, condition, and materials of construction for the chimney, corbel, barrel, bench and channel and their current condition and evidence of I/I.

- Photographs are obtained and entered into the system for location views and top down views of the manhole; photographs are also collected for the pipe connections and any significant defects when possible.

- Pipe sizes are recorded and located according to clock position with the outgoing pipe always being the 12 o'clock position. Pipe diameter and rim to invert depths are also collected and recorded in MIAS along with the condition of the pipe seals.

- All manholes are then assigned a 1-5 condition rating, with 1 being in excellent condition and 5 being in very poor condition and requiring immediate attention.

In order to prioritize the maintenance and repair of the manholes, a condition rating scale was used to weight the various types of structural defects and I/I conditions that occurred in different components of the manhole structure. This rating system also allowed for the characterization of operation and maintenance (O&M) type issues such as identification of fats, oils and grease (FOG), debris accumulations, surcharging of the manhole and other O&M type issues. During the initial phase of this project, NASSCO introduced a standard for manhole condition assessment. This standard was the Manhole Assessment and Certification Program (MACP), which was subsequently adopted by the City to aid in the consistency of data collected and to provide for a reliable evaluation of each manhole component. The use of this standard provides a baseline condition assessment of the structure, which aids in providing a consistent review of conditions during future inspections. The 1-5 condition rating standard used for the manhole inspections is largely based on the ASCE Manual of Practice No. 92, which utilizes a 5-point severity rating system. The following represents the rating scale:

1. Excellent Condition – Only minor defects
2. Good Condition – Defects have not started to deteriorate
3. Fair Condition – Moderate defects that will continue to deteriorate
4. Poor Condition – Severe defects likely to become a grade 5
5. Immediate Attention Required – Defects requiring immediate attention

Table 4.2.1 and 4.2.2 provides an overview of the condition of the 2,195 manholes inspected as part of the Outfall Sewershed manhole inspection program and classifies the manholes by overall structure rating. The manhole condition rating of the 47 manholes associated with the Outfall Interceptor, Outfall Relief and 99-inch Sewers are presented separately from the rest of the manhole ratings in Table 4.2.2.

It should be noted, that not all the manhole inspections associated with the Outfall Interceptor, the Outfall Relief, and 99-Inch Sewers have been completed at the time of this draft. Manholes that are accessible are anticipated to be completed by the end of February, 2010, and the results, noted deficiencies, and recommended improvements will be incorporated into the next draft submittal.

Table 4.2.1 - Manhole Condition Rating Summary - On Sewers < 99"		
Rating	**Count**	**%**
5 - Defects that require immediate attention	2	0.1%
4 - (Poor)	13	0.7%
3 - (Fair)	1,586	80.8%
2 - (Good)	46	2.3%
1 - (Excellent)	0	0.0%
*Missing Rating**	316	16.1%
TOTAL MANHOLES INSPECTED	**1,963**	**100%**

Table 4.2.2 - Manhole Condition Rating Summary - On Sewers 99" & Larger		
Rating	**Count**	**%**
5 - Defects that require immediate attention	0	0.0%
4 - (Poor)	0	0.0%
3 - (Fair)	31	53.4%
2 - (Good)	0	0.0%
1 - (Excellent)	0	0.0%
*Missing Rating**	27	46.6%
TOTAL MANHOLES INSPECTED	**58**	**100%**

** These are the manholes that could not be located or could not be opened for inspection.*

Table 4.2.3 provides an overview of the general manholes defect quantities within the 1,963 manholes located on sewers less than 99-inches in diameter.

Table 4.2.3 - General Manhole Defect Summary - On Sewers < 99"		
Description	**Count**	**%**
Frame leaks	1,005	51.2%
Chimney leaks	1,545	78.7%
Corbel leaks	1,513	77.1%
Barrel leaks	1,508	76.8%
Bench leaks	12	0.6%
Channel leaks	4	0.2%

Table 4.2.4 provides an overview of the general manholes defect quantities within the 58 manholes located on sewers with diameters 99-inches and larger.

Table 4.2.4 - General Manhole Defect Summary - On Sewers 99" & Larger		
Description	**Count**	**%**
Frame leaks	26	44.8%
Chimney leaks	16	27.6%
Corbel leaks	28	48.3%
Barrel leaks	26	44.8%
Bench leaks	0	0.0%
Channel leaks	0	0.0%

Table 4.2.5 provides an overview of the total number of defects observed, classifying the conditions by defect type within the 1,963 manholes located on sewers less than

99-inches in diameter. Attachment 4.2.1 contains all manhole inspection reports completed for this project.

Table 4.2.5 - Manhole Defect Location Summary - On Sewers < 99"

Description	Count	%
MH Cover Defects	9	0.2%
MH Frame Defects	1,059	20.2%
MH Chimney Defects	1,051	20.1%
MH Corbel Defects	73	1.4%
MH Barrel Defects	66	1.3%
MH Bench Defects	937	17.9%
MH Channel Defects	683	13.1%
MH Steps	1,353	25.9%
Total:	**5,231**	**100%**

Table 4.2.6 provides an overview of the total number of defects observed, classifying the conditions by defect type within the 58 manholes located on sewers with diameter 99-inches and larger.

Table 4.2.6 - Manhole Defect Location Summary - On Sewers 99" & Larger

Description	Count	%
MH Cover Defects	1	0.9%
MH Frame Defects	28	25.9%
MH Chimney Defects	6	5.6%
MH Corbel Defects	2	1.9%
MH Barrel Defects	9	8.3%
MH Bench Defects	30	27.8%
MH Channel Defects	5	4.6%
MH Steps	27	25.0%
Total:	**108**	**100%**

4.3 Sewer Cleaning and Closed Circuit Television Inspection (CCTV)

Internal inspection of sewer pipes is the process of inspecting and documenting the condition of the pipes by means of CCTV. It also provides valuable insight into the cleaning and maintenance requirements of each sewer segment and provide information that is needed to assign appropriate rehabilitation technologies to deteriorated or damaged pipe segments.

To provide the highest visibility of defects, all sewers inspected were cleaned prior to inspection to accurately define the conditions. Sewers were cleaned utilizing hydraulically propelled high-velocity jet or other mechanically powered equipment. The intent of the cleaning operations was twofold. First, to adequately clean the sewer so the inspection could identify defects that otherwise would not be visible and second, to remove all foreign materials from the sewer to restore the sewer to a minimum of 95% of its original carrying capacity. When significant restrictions such as roots or other heavy debris restrictions were encountered, heavy cleaning was utilized to restore

the capacity of the sewers and allow for internal inspection. Heavy cleaning involved root cutting or additional passes of the hydro-cleaning equipment. All debris was removed from the sewers. When significant blockages were identified, they were reported to the City and the City promptly coordinated with the wastewater maintenance division or their on-call contractor to resolve the deficiencies.

Following cleaning, the sewer segments were inspected by means of CCTV. These inspections were used to identify the following:

- Current pipe condition including existing or potential structural deficiencies or problems, and accurately identifying the pipe's connectivity and location.
- Confirmation, extent and current condition of previous rehabilitation projects and/or repairs.
- Identifying improper or potentially illicit connections.
- Identifying potential sources of I/I.
- Assist in selecting appropriate methods of repair, rehabilitation and/or replacement.

Paragraph 9 of the CD requires that gravity sewers eight (8) inches and larger in diameter be inspected using CCTV inspection in accordance with NASSCO guidelines. The CCTV inspection of the sewers provided the necessary condition assessment for the SSES evaluation of the Outfall Sewershed. The inspections identified defects and other problems relating to the sanitary sewer collection and conveyance system that allows the project team to compile a comprehensive corrective action plan and prioritize an implementation schedule.

All CCTV inspections were completed and data collected according to NASSCO's Pipeline Assessment and Certification Program (PACP) guidelines and standards. The City required the use of PACP certified software to collect and record all CCTV information. All CCTV operators, equipment and the review team were certified in the use of the PACP coding system.

All CCTV inspections were conducted using a color pan-and-tilt, radial viewing inspection camera that provides adequate illumination to clearly observe defects and other features within the pipe. All surveys were initiated from the upstream manhole proceeding downstream with the flow to minimize splashing of the camera. When defects or other obstructions prevented the completion of the inspection in this direction, a reverse inspection was initiated from the downstream manhole to complete the inspection of the sewer segment. The CCTV camera lens was required to be positioned in the center of the pipe being inspected and movement of the camera through the sewer pipe did not exceed a speed of 30-feet per minute. Wastewater flows in the sewer during the inspection were controlled and did not exceed 20 percent of the pipe capacity for pipes 8"- 10"; 25 percent for pipes 12"- 24", and 30 percent for pipes 24" and larger per the PACP guidelines. During the internal inspection, the CCTV camera was temporarily stopped at all significant defects and side sewer or service

connections to accurately code and provide a clear image of the defect or point of connection. For larger sewer inspections where it was not practical or when flows could not safely or effectively be reduced, sonar inspection or a combination of sonar and CCTV inspection was used to inspect the sewers. The use of a combination CCTV/sonar camera allowed for the visual inspection of the sewer above the flow line and the sonar provided inspection information below the flow of the sewer.

As a means to prioritize the maintenance and repair of pipe sections and other associated sewer appurtenances, a condition rating scale was used to rate the various types and degrees of structural defects and I/I conditions occurring in different segments of the sanitary sewer system. The PACP rating scale was utilized as a standard and consistent format for the way pipes were evaluated and conditions recorded. These standards allow pipe conditions to be reported in a standard recognized manner and allow the City to compare the segment's condition from one time frame to another and accurately track the condition of the pipe and any progression of defects.

The PACP coding system requires the assignment of a specific code for each structural and O&M type defect identified within a pipe segment. The software automatically assigns a PACP rating code to each defect when entered. These grades are assigned based on the potential for further deterioration or possible failure of the pipe.

The PACP grading system obtained from NASSCO's "Pipeline Assessment and Certification Program" reference manual utilized for this project is as follows:

Grade	Description	Time to Failure
5	Immediate Attention Required	Pipe has failed or will fail within 5 years
4	Poor	Pipe will probably fail within 5 to 10 years
3	Fair	Pipe may fail in 10 to 20 years
2	Good	Pipe unlikely to fail for at least 20 years
1	Excellent	Failure unlikely in the foreseeable future

Utilizing this system, each pre-defined defect or observation code is directly associated with a severity rating based on the type and extent of the defect. These ratings aid in determining the need for maintenance, repair, rehabilitation or replacement of the pipe segment. The PACP software assigns a four-digit severity code, or PACP quick rating for each sewer segment inspected and contained in the database. These ratings, in conjunction with the critically rating of the system component were what were used to prioritize system repairs.

Tables 4.3.1 and 4.3.2 summarize the defects recorded during the CCTV inspections by type of defect and also by overall segment condition rating. Table 4.3.3 summarizes the O&M conditions. Attachment 4.3.1 is an Access database that contains all CCTV

inspection information completed as part of the CCTV inspection program in the Outfall Sewershed.

Table 4.3.1 - CCTV Defect Observation Summary

CCTV Inspection Defects		Pipe Diameter						
Family	Group Type	8" - 12"	14" - 18"	20" - 33"	36" - 56"	60" - 96"	>96"	Total
Structural	Broken or Hole	621	5	7	0	0	1	634
Structural	Collapse	8	0	0	0	0	0	8
Structural	Cracks	5,048	87	129	0	0	49	5,313
Structural	Defective Joints	570	0	2	0	0	0	572
Structural	Defective Lining	39	0	0	0	0	12	51
Structural	Deformation	50	0	0	0	0	0	50
Structural	Encrustation & Scale	120	1	0	0	4	343	468
Structural	Fracture	3,933	44	67	0	0	6	4,050
Structural	Repair	112	1	0	0	0	0	113
O&M	Encrustation & Scale	1,804	53	66	0	0	159	2,082
O&M	Grease	1,362	18	31	0	0	0	1,411
O&M	Infiltration	176	30	10	0	0	118	334
O&M	Obstruction	677	23	20	0	0	5	725
O&M	Roots	2,362	38	26	0	0	4	2,430
O&M	Settled Deposits	1,321	45	25	0	2	180	1,573
Constructional	Defective Tap	1,563	29	17	0	0	8	1,617
Constructional	Line Deviations	179	2	3	0	0	57	241
Constructional	Obstruction	131	0	3	0	0	9	143
Misc	Camera Underwater	38	2	0	0	0	4	44
Misc	Survey Abandoned	449	12	6	0	1	3	471
Misc	Water Level >20%	1,058	24	21	0	1	95	1,199
	Total:	**21,621**	**414**	**433**	**0**	**8**	**1,053**	**23,529**
	Percent:	**91.9%**	**1.8%**	**1.8%**	**0.0%**	**0.0%**	**4.5%**	**100%**

Table 4.3.2 - Sewer Overall Condition Rating Summary - For Sewers < 99"

Rating	Pipe Segments		Pipe Lengths	
	Count	%	Feet	%
5 - Defects that require immediate attention	11	0.6%	2089	0.7%
4 - (Poor)	8	0.4%	1,975	0.6%
3 - (Fair)	17	0.9%	4,185	1.4%
2 - (Good)	85	4.4%	19,292	6.3%
1 - (Excellent)	1,426	73.2%	229,229	75.4%
Missing pipes	401	20.6%	47,215	15.5%
Total:	**1,948**	**100%**	**303,985**	**100%**

Table 4.3.3 - Sewer Operation and Maintenance Condition Rating Summary - For Sewers < 99"				
Rating	Pipe Segments		Pipe Lengths	
	Count	%	Feet	%
5 - Defects that require immediate attention	9	0.5%	2,397	0.8%
4 - (Poor)	9	0.5%	2,228	0.7%
3 - (Fair)	51	2.6%	13,644	4.5%
2 - (Good)	196	10.1%	40,752	13.4%
1 - (Excellent)	1,282	65.8%	197,750	65.1%
Missing pipes	401	20.6%	47,215	15.5%
Total:	**1,948**	**100%**	**303,985**	**100%**

Closed Circuit Television (CCTV) / Sonar Inspections

For the Outfall Interceptor, Outfall Relief, and 99-inch Sewers, flows could not be effectively reduced to allow for inspection by CCTV Camera only. Thus, the Outfall Interceptor, Outfall Relief, and 99-inch sewers were inspected by use of a combination CCTV / Sonar Camera. The CCTV allowed for visual inspection of the sewers above the flow line, and the sonar provided inspection information below the flow line.

The CCTV inspections revealed exposed aggregate along the sidewall of all three sewers, and areas of missing aggregate along the crown of the pipe and along the flowline of pipe of all three sewers. The Outfall Interceptor and the 99-inch Sewers, with some minor exceptions, are unreinforced concrete structures. Without steel reinforcement in the pipe to act a point of reference, it was not possible to accurately determine from CCTV Tapes the extent of wall material loss. This was also an issue with the Outfall Relief Sewer.

Table 4.3.1 summarizes the defects, for all pipe sizes, recorded during the CCTV inspections by type of defect. Table 4.3.4 summarizes the defects, in the Outfall Interceptor, Outfall Relief and 99-inch sewers, by overall segment condition rating. Table 4.3.5 summarizes the O&M conditions for the three large diameter sewers.

Table 4.3.4 - Sewer Overall Condition Rating Summary - For Sewers 99" & Larger				
Rating	Pipe Segments		Pipe Lengths	
	Defect Count	%	Feet	%
5 - Defects that require immediate attention	5	4.4%	1,439	5.7%
4 - (Poor)	2	1.8%	663	2.6%
3 - (Fair)	100	87.7%	22,888	90.6%
2 - (Good)	1	0.9%	2	0.0%
1 - (Excellent)	6	5.3%	275	1.1%
Total:	**114**	**100%**	**25,267**	**100%**

Table 4.3.5 - Sewer Operation and Maintenance Condition Rating Summary - For Sewers 99" & Larger				
Rating	**Pipe Segments**		**Pipe Lengths**	
	Defect Count	**%**	**Feet**	**%**
5 - Defects that require immediate attention	0	0%	0	0.0%
4 - (Poor)	36	31.6%	8,765	34.7%
3 - (Fair)	73	64.0%	15,309	60.6%
2 - (Good)	0	0%	0	0.0%
1 - (Excellent)	5	4.4%	1,193	4.7%
Total:	**114**	**100%**	**25,267**	**100%**

Due to amount of flow in the large sewers, Sonar inspection below the flow line was conducted in conjunction with the CCTV inspection. Sonar inspection revealed accumulation of debris in the large sewers.

- Sediment / debris build-up in the Outfall Interceptor ranges from 21 inches up to 42 inches along the entire length.
- Sediment / debris build-up in the Outfall Relief Sewer ranges from 21 inches up to 41 inches. In one 400 foot segment, half of the pipe is filled with sediment / debris.
- Sediment / debris build-up in the 99-inch Sewer ranges from 10 inches up to 21 inches along the entire length.

4.4 Smoke Testing

Smoke testing was utilized by the project team as a means to quickly and effectively identify potential locations of stormwater/groundwater entry into the sanitary sewer collection system. Direct connections including downspouts, area drains, driveway drains, stairwell drains, patio drains, and storm sewer inlets or ditches can be confirmed with smoke testing. Indirect connections from storm sewers or drainage ditches, which allows I/I to pass through soil and into deteriorated or damaged conveyance piping, can also be identified with smoke testing.

Map 4.4.1 shows the meter basins that were smoke tested and the ones that were not. The smoke testing operations for this project were conducted between June and July 2008, during periods when the groundwater table was low and with sufficient time having elapsed from any prior rain events. Smoke testing was not allowed to be completed until 24-hours had passed from a wet-weather event to make sure the soils were sufficiently dry to allow detection of smoke. Prior to initiating the smoke testing, an extensive list of property owners, hospitals, nursing homes, schools, daycares, local civic and community leaders, community associations, council members, and police and fire officials were notified. This process included monthly testing notifications and the distribution of detailed smoke testing door hanger notifications, typically extending two blocks outside the test areas three days prior to conducting the tests. When smoke testing was initiated and subsequently stopped because of rain, re-initiation of the testing did not occur until conditions were again suitable and the notification process

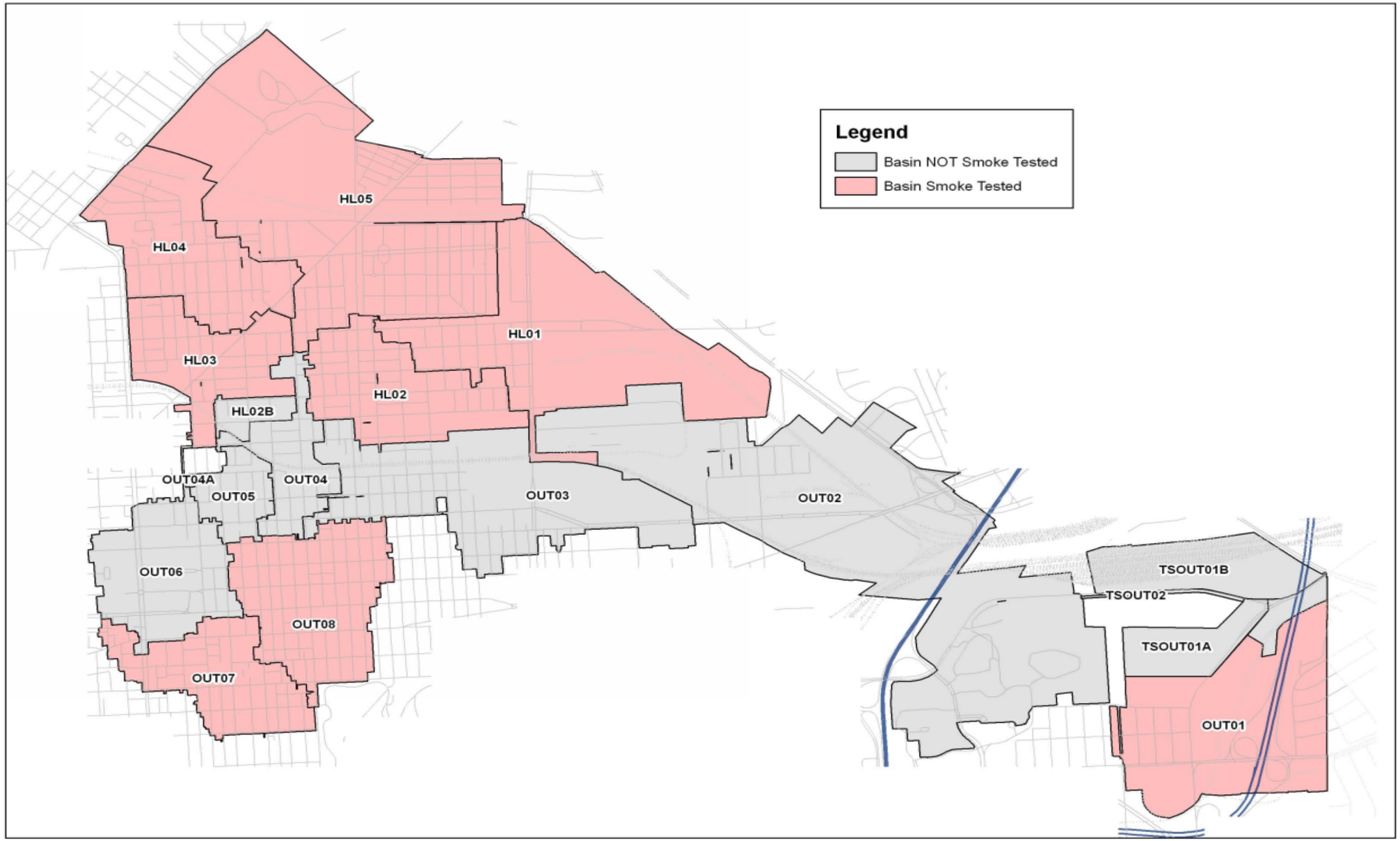
was completed again. In most cases smoke testing was conducted using a single blower setup technique with smoke being introduced at the smoke blower and pushed through isolated sections of the pipe. The maximum allowable set-up length was no more than two total manhole reaches. A manhole reach is defined as a manhole to manhole segment of the sewer. Field crews were responsible for determining that adequate smoke coverage was obtained by observing smoke concentrations and observing smoke travel using house plumbing vents along the setup. Smoke was continually introduced into the test setup manhole until adequate smoke coverage was obtained in the test area. In the event that smoke did not travel the entire reach, the setup was reversed by setting the blower on the opposing manhole of the initial setup and re-introducing the smoke. Such situations were often caused by pipe sags that contained flow, grease, debris, collapsed pipes, or other obstructions that would prevent smoke from traveling through the pipe. All instances were documented as a potential maintenance problem and reported to the City.

Both the upstream and downstream manholes were isolated during the smoke testing to concentrate the smoke within the test section. These restrictions were accomplished using sandbags or air plugs. In situations where heavier smoke concentrations were required, a dual blower technique was utilized with a blower placed on both the upstream and downstream manholes and smoke generated at each blower setup. The maximum set-up length in this situation was typically limited to 1,000 LF. Suspect inflow sources such as driveway drains, stairwell drains, window well drains, patio and area drains, and downspouts piped underground, or foundation drains were noted. Significant potential sources of "clear water" connections (such as storm drain or catch basin connections) were noted and were recommended for follow-up dyed-water testing to determine if actual cross connections existed. Care was taken to inspect the property around all buildings for sources of smoke. In situations where heavy smoke exited a source and it could be determined and documented through observation that the source was directly connected to the sanitary sewer, further investigation was not necessary. Generally, in all other situations where it could not accurately be determined if the source was directly connected to the sanitary sewer, further dyed-water testing was scheduled.

Table 4.4.1 summarizes the defects identified during the smoke testing inspections, identified by type of defect or source, defect location, sector (public or private) and the severity of the defect. Attachment 4.4.1 contains all smoke testing inspection data completed for this project.

Table 4.4.1 - Smoke Testing Defect Summary													
Sector	**Total Defects**											**Percent Total (%)**	
Public	160											21.78%	
Private	555											78.22%	
Total:	**715**											**100%**	
Source Type	**Sub-Sewersheds**												
	HL01	**HL02**	**HL03**	**HL04**	**HL05**	**OUT01**	**OUT02**	**OUT03**	**OUT07**	**OUT08**	**No Basin**	**Total Observations**	**Percent Total (%)**
Building - Interior	1				1				1			3	0.42%
Cleanout	24	23	7	126	47	79			10	10	9	335	46.85%
Downspout		2			2							4	0.56%
Foundation Drain	1											1	0.14%
Lateral	4	10	5	48	61	39	1	1	9	20	5	203	28.39%
Lateral/Cleanout					3							3	0.42%
Main Sewer	1	2	3	35	27		1		5	1	4	79	11.05%
Main Sewer/Lateral				1								1	0.14%
Manhole Frame	6	3		4	3					2		18	2.52%
Other	12	8		2	4	1						27	3.78%
Storm Drain	3	7		2	3	4		1		4		24	3.36%
Storm Manhole		1				1						2	0.28%
Telephone Pole		1		4	3		1				2	11	1.54%
Water Line	1			1						2		4	0.56%
Total:	**53**	**57**	**15**	**223**	**154**	**124**	**3**	**2**	**25**	**39**	**20**	**715**	**100%**

Defect items in Table 4.4.1 that were coded as 02 – Service Connections, 03 – Cleanouts, 04 – Downspouts, 05 – Area Drains, 06 – Driveway Drains, 07 – Stairwell Drains, 08 – Foundation Drains, 09 – Building Interior, 11 – Storm Drain, 12 – Catch Basin/inlet, 13 Storm Manhole and 14 – Storm Ditch were scheduled for additional investigation utilizing dyed-water testing.



Map 4.4.1: Smoke Tested Basins

4.5 Dyed-Water Testing

The dyed-water testing or flooding of areas identified in Table 4.4.1 such as storm drain catch basins were conducted as part of the study of the Outfall sewershed collection system. The dyed-water flood test aided the project team in detecting pipe segments that were either direct or indirect connections between the storm drain and sanitary sewer system. Direct connections were typically confirmed during the smoke testing operations; however, any suspect locations were further investigated using dyed-water flooding or tracing. To complete this testing, the suspect storm drain, catch basin or other area was flooded with dyed-water and the adjacent connecting sanitary sewer manholes were observed for the presence of dye in the flow. In more detailed situations, the storm drain was plugged and filled with dyed-water and allowed to sit for an extended period of time to allow the dyed-water to permeate the surrounding soils and identify leakage points in the collection system piping. Typically a waiting period of at least thirty minutes following the initiation of the dyed-water was used before the test could be considered negative. The CCTV survey records performed in the vicinity of the defects were reviewed to determine if the defects were illegal connections. The existence of illegal connections was not observed in the CCTV surveys and the defects are considered to be indirect connections.

Table 4.5.1 summarizes the tests by location and type, and identifies all locations where dyed-water was observed through defects during the dyed-water testing inspections. Attachment 4.5.1 contains all dyed-water tests completed as part of this project.

Table 4.5.1 - Dyed-Water Testing Defect Summary

Sector	Count	Percent
Public	20	100.0%
Private	0	0.0%
Total	**20**	**100%**
Source	**Count**	**Percent**
Mainline	13	65.0%
Service Line	5	25.0%
Cleanout	0	0.0%
Downspout	0	0.0%
Area Drain	0	0.0%
Driveway Drain	0	0.0%
Stairwell Drain	0	0.0%
Foundation Drain	0	0.0%
Building Interior	0	0.0%
MH Frame/Seal	2	10.0%
Storm Drain	0	0.0%
Catch Basin/Inlet	0	0.0%
Storm Manhole	0	0.0%
Storm Ditch	0	0.0%
Excavation	0	0.0%
Other	0	0.0%
Total	**20**	**100%**

Note: Does not include Dyed-Water Testing results from OUT01 meter basin

4.6 Emergency Repairs / Rehabilitation

In accordance with Paragraph 9 Item C.iii of the Consent Decree, all significant system deficiencies observed during field inspections or when reviewing the field data were reported to the City. Figure 4.6.1 indicates the location of reported deficiencies and includes those discovered by everyday City operations.

4.7 Pumping Station Evaluations

There are no pump stations within the Outfall sewershed.

4.8 Quality Assurance / Quality Control Procedures

The following sections provide the reader with a brief description of the Quality Assurance / Quality Control (QA/QC) review process that all inspections underwent before they were considered complete and delivered to the City. In addition, copies of the Manhole Condition Rating and Defect Manuals, CCTV Review Manual and Smoke and Dyed-Water Testing Procedures Manuals developed by RK&K to insure the consistency and accuracy of the data being provided to the City are included as Attachments 4.8.1 through 4.8.4 of this report.

4.8.1 Manhole Inspection QA / QC Procedures:

- MIAS contains several internal field checks, which prompt the inspector to verify information as it is entered. (e.g.: if an inspector enters the invert elevation of an outgoing pipe at a higher elevation than the incoming pipe's invert elevation, the check prompts the inspector to verify the information). Several of these internal checks will not allow the inspector to move on to the next entry item in the inspection until the prior inspection item has been successfully completed.

- Basic information regarding location and system connectivity was compared with existing information or contract documents. Connecting manhole nodes entered in MIAS were compared to what was shown on the mapping and corrections made as necessary.

- All information was reviewed, which included reviewing for errors, assuring photograph quality and reviewing all comments entered by the inspector for clarity and content.

- If there was information missing, the MIAS record was failed and returned to a field crew to revisit the site and collect the required information or the reviewer would utilized existing record documents to obtain the required information.

- When the follow-up information was collected by the field crew or addressed by the reviewer utilizing record data, the new information was again reviewed and if acceptable, added to the record. The record was then tagged as QA/QC complete and flagged for submittal to the City.

4.8.2 CCTV Inspection QA / QC Procedures:

- All CCTV inspections were reviewed for conformance with PACP coding guidelines (video quality, flow levels, header information, all defects coded, and coded properly).

- Review all CCTV footage and inspection logs for significant defects such as collapsed pipe, blockages, etc. and forwarded these defects to the City for action.

- Review CCTV footage and inspection logs for significant O&M items such as excessive grease, roots, etc. and forwarded these defects to the City for action.

- If issues were found with video quality or PACP coding of defects for the segment inspected, the inspection record was returned to the CCTV contractor with review comments for recoding or re-surveying.

4.8.3 Smoke Testing QA / QC Procedures:

- All completed field reports were reviewed for conformance to the project guidelines and accuracy assuring that all maps, defect information and photographs are complete, clear, accurate and compatible.

- Review all smoke testing entries entered into the Access database to assure all observations and photographs are in accordance with the database scheme and specifications outlined for the project.

- If any field data collected was questionable, incomplete or illegible, the data was returned to the responsible contractor with review comments for correction and resubmission.

- Review all data submitted to identify significant defects such as cross connections. Any significant findings were reviewed and if required, assigned for further evaluation utilizing dyed-water testing.

4.8.4 Dyed-Water Testing QA / QC Procedures:

- All completed field data was reviewed for conformance with the project guidelines and accuracy requirements assuring that all maps, defect information and photographs are complete, clear, accurate and compatible.

- All dyed-water testing information was entered into the Access database to assure all observations and photographs are in accordance with the database scheme and specifications outlined for the project.

- If any field data collected was questionable, incomplete or illegible, the data was returned to the responsible contractor with review comments for correction and resubmission.